A New Methodology for Estimating the Unpredictable Component of Seasonal Atmospheric Variability

ARUN KUMAR

Climate Prediction Center, NCEP/NOAA, Camp Springs, Maryland

BHASKAR JHA AND QIN ZHANG

RSIS, Climate Prediction Center, NCEP/NOAA, Camp Springs, Maryland

LAHOUARI BOUNOUA

Biospheric Sciences Branch, Goddard Space Flight Center, Greenbelt, Maryland

(Manuscript received 19 January 2006, in final form 20 September 2006)

ABSTRACT

Predictability limits for seasonal atmospheric climate variability depend on the fraction of variability that is due to factors external to the atmosphere (e.g., boundary conditions) and the fraction that is internal. From the analysis of observed data alone, however, separation of the total seasonal atmospheric variance into its external and internal components remains a difficult and controversial issue. In this paper a simple procedure for estimating atmospheric internal variability is outlined. This procedure is based on the expected value of the mean square error between the observed and the general circulation model simulated (or predicted) seasonal mean anomaly. The end result is a spatial map for the estimate of the observed seasonal atmospheric internal (or unpredictable) variability. As improved general circulation models become available, mean square error estimated from the new generation of general circulation models can be easily included in the procedure proposed herein, bringing the estimate for the internal variability closer to its true estimate.

1. Introduction

Predictability of seasonal climate anomalies can arise from two possible sources: 1) boundary conditions external to the atmosphere [e.g., sea surface temperatures (SSTs)] and 2) atmospheric initial conditions. Within the paradigm of seasonal atmospheric predictability due to external boundary conditions, the potential for skillful predictions depends on the fraction of the atmospheric seasonal mean variability that is related to the anomalous boundary conditions and the fraction that is internal to the atmosphere. The influence of the anomalous boundary conditions on the atmospheric seasonal variance can be further augmented by the influence of atmospheric initial conditions, and in general, this influence depends on the separation between the initial condition and the target forecast season (i.e., the forecast lead time).

Based on observational data alone, however, the separation of seasonal atmospheric variance into its external and internal components, as well as determining the influence of atmospheric initial conditions on seasonal mean variability, remain difficult and controversial tasks. The difficulty arises because for the individual realizations of observed seasonal mean atmospheric anomalies, the estimation of boundary forced and internal components of the atmospheric variance, as well as the influence of initial conditions on them, cannot be made. Alternate approaches for the estimation of seasonal internal variability based on the daily atmospheric variability have been proposed (Madden 1976; Shea and Madden 1990). These methods rely on the analysis of the autocorrelation of daily observations to infer the variance of monthly and seasonal time averages and their comparison with the corresponding ob-

Corresponding author address: Dr. Arun Kumar, Climate Prediction Center, 5200 Auth Rd., Rm. 800, Camp Springs, MD 20746.
E-mail: arun.kumar@noaa.gov

DOI: 10.1175/JCLI4216.1

served interannual variability. Such methods also rely on various assumptions (e.g., changes in boundary conditions have no influence on the characteristics of daily variability). Such assumptions could lead to erroneous estimates for the internal and external variability of seasonal means (Shukla 1983; Trenberth 1984; Zwiers 1987).

An alternate approach for estimating seasonal climate predictability is the use of atmospheric general circulation models (AGCMs). For example, for decomposition of the seasonal mean atmospheric variability into its internal and external components, long multiple realizations of AGCM simulations starting from different atmospheric initial conditions, but forced with identical evolution for the observed boundary conditions (the so called AMIP simulations), are made. The ensemble mean of the AGCM-simulated anomaly is the atmospheric response to the observed boundary forcing, whereas the departure from the ensemble mean is the component of seasonal mean that is internal to the atmosphere, making it possible to estimate the atmospheric external and internal variances (Barnett 1995; Harzallah and Sadourny 1995; Kumar and Hoerling 1995). A similar setup can also be used for estimating the influence of atmospheric initial conditions on seasonal means; except for this case, AGCM simulations, in contrast to the long AMIP integrations, start from observed initial conditions and are of short duration (Branković and Palmer 2000; Shukla et al. 2000).

Although ensemble AGCM simulations can be used to decompose seasonal mean atmospheric variability into its external and internal components, such a procedure leads to an estimate that is an AGCM's rendition of observed atmospheric variability and could be biased by the AGCM errors. Indeed, AGCM-based estimates of external and internal components of seasonal mean variability show a large range of variations from one AGCM to another (Shukla et al. 2000; Kumar et al. 2000).

To lessen the influence of AGCM biases, in this paper an approach for estimating the upper bound for the observed internal variability is outlined, based on the aggregation of simulations from many different AGCMs. This procedure provides a local measure for the seasonal mean atmospheric internal variability. The estimate depends on the selection of the least-biased AGCM among the collection of AGCM simulations one has. Further, as models improve, the procedure described in this paper can incorporate ensemble simulations from the next generation models, and estimates for the observed atmospheric internal variability obtained herein can be easily updated. The procedure for estimating the atmospheric internal variability is described in section 2, and results are presented in section 3. As our estimates for the internal and external variance in section 3 are based on the specification of SST boundary conditions alone, a discussion in section 4 includes a review of factors that are not included in our analysis but may influence estimates of external and internal variance (e.g., the influence of atmospheric initial conditions, coupled air–sea interactions, etc.). Concluding remarks are presented in section 5.

5. Concluding remarks

The estimate for the internal variability of DJF 200-mb observed seasonal mean heights in Fig. 4 is our best estimate of the observed internal (or unpredictable) component of variability based on the current generation of AGCMs (and data available to us) that is not related to the observed history of SSTs. Similarly, Fig. 8 replicates the best estimate of the predictability of seasonal atmospheric climate anomalies based on the DEMETER dataset that includes the influence of observed ocean, atmosphere, and land initial states, as well as the influence of realistic coupling between different components of the earth's system. Simulations from the future generation of model integrations and the corresponding spatial map for MSE can be used to update the spatial map of the unpredictable component of variability in Fig. 4 (and in Fig. 8). At the geographical locations, where the MSE for models is higher than the current estimate, this will not lead to any update in the estimate of the unpredictable component of variability. Only at the geographical location where the estimate of MSE is lower than the estimate of variability in Fig. 4 (Fig. 8) will a lower (higher) estimate of atmospheric internal variability seasonal climate predictability be found. It remains to be seen how much of the internal variability from estimates based on the current generation of the model simulations, and shown in Figs. 4, 8, can be moved to the variance that is predictable because of the improved models, higher resolution, improved initial conditions, etc. Based on the unique properties of MSE, in this paper we provide a methodology that could be used to document such improvements.